CS5150 Embedded Processor Design
Midterm Report
Portable MP3 Player Design

Chih-Wea Wang
d897909

1 Introduction

The demands of high quality digital audio application are now being popular. The standardized MPEG format of audio compression schemes is one of the solution for high-quality audio transmission within the past few years. During that time, MPEG-1 Layer 3 (MP3) has become the audio compression standard used on the Internet.

The basic elements of the MP3 decoding algorithms are roughly divided into several sections: bit stream demultiplex, Huffman decoding of the spectral values, requantization and frequency-to-time mapping. Fig. 1 shows the ¤ow of decoding process. Frequency-to-time mapping is realized via hybrid £lter banks in MP3. The algorithm starts by mapping the time signal to the frequency domain. Huffman encoding performs redundancy reduction of the quantized spectral data. Finally, side information and audio data are multiplexed into an MPEG bit stream.

Inside the decoder, the £lter bank is the most time-consuming algorithm section, while the T/F mapping ranks as the most complex on the encoder side. Sections of similar complexity are the psychoacoustic model and the quantization stage. The basic operation behind ef£cient implementations is a fast Fourier transform (FFT) butter¤y. Because of rounding errors of 1/2 least signi£cant bit (LSB) in each stage of the transform, there's a theoretical loss of accuracy of 4.5 bits in the transform. A minimum width of 20 bits in the data path is required, with 24 bits being better, to reach the full dynamic range of a CD's native 16-bit data format without any loss in accuracy.

There are different requirements for the encoder control path. The calculation of the masking thresholds in the psychoacoustic model deals with energies per scale factor. The precision requirements are much lower than for the data path. On the other hand, the dynamic range of energies is much higher than in the data path.

The amount of memory depends on the ef£ciency of the implementation. Some research shows that about 4k words of RAM for I/O and processing buffers are suf£cient for MPEG Layer 3 in stereo mode. For Huffman tables, quantizer tables, twiddle factors, polyphase window coef£cients and the like, about 3 k words of data ROM are required. The computational power very much depends on the ef£ciency of the instruction set and the underlying processor architecture.

Each algorithm phase mentioned above places speci£c demands on the architecture. For example, the basic instruction for digital signal-processing algorithms is the multiply-accumulate (MAC) operation. Most DSP executes a MAC operation in a single clock cycle. To meet the computation requirement, a DSP is the better choice.Texas Instruments Inc.'s new C55xx device, for example, comes with a dual MAC. It would have been wise to foresee a mode that would couple both 16-bit MACs in such a way that a 32 x 32 MAC could execute in a single clock cycle.

Beside the DSP, a general purpose microcontroller is needed. It deals with the data transfer between ¤ash memory, I/O interface and DSP. The performance of this controller is not the bottleneck due to the low speed of I/O and control.
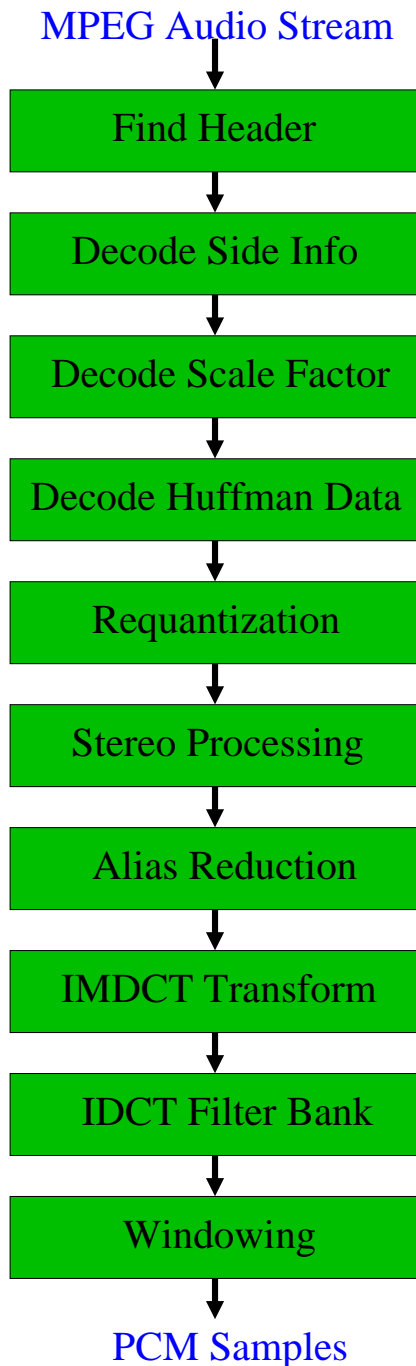
MPEG Audio Stream

```
┌─────────────────────────┐
│       Find Header       │
└─────────────────────────┘
             │
┌─────────────────────────┐
│     Decode Side Info    │
└─────────────────────────┘
             │
┌─────────────────────────┐
│   Decode Scale Factor   │
└─────────────────────────┘
             │
┌─────────────────────────┐
│   Decode Huffman Data   │
└─────────────────────────┘
             │
┌─────────────────────────┐
│     Requantization      │
└─────────────────────────┘
             │
┌─────────────────────────┐
│    Stereo Processing    │
└─────────────────────────┘
             │
┌─────────────────────────┐
│     Alias Reduction     │
└─────────────────────────┘
             │
┌─────────────────────────┐
│     IMDCT Transform     │
└─────────────────────────┘
             │
┌─────────────────────────┐
│    IDCT Filter Bank     │
└─────────────────────────┘
             │
┌─────────────────────────┐
│       Windowing         │
└─────────────────────────┘
             │
```

PCM Samples

Figure 1: The ¤ow of MP3 decoding.

2 Requirements

The MP3 player is one of portable consumer product. That means it should be light, low power and novel as well as low cost. There are many brands of MP3 player on the market. Comparing with them, our product should meet the same requirement and feature to compete with other rival commodities. A 64MB ¤ash memory is the minimal requirement. It can store about 10 to 15 MP3 audio £les. An extending storage media is better, but the cost and complexity should be also considered. To download and manage the internal ¤ash storage, a host system is required. Most products use the PC as the host system, and a USB connection is a popular consideration. Likes the traditional CD player or walkman, a simple LCD displayer with a few digits and several bottoms for controlling are also the requirement. The wired earphone is the basic component of player. But the wireless earphone is more attractive. The bluetooth headset is a good choice. The proposed MP3 player supports the bluetooth headset with the bluetooth supporting mobile phone. When the phone getting a call, the headset can switch to phone from MP3 player automatically. The inputs contains 4 buttons that are Play/Power key, Stop, and two function keys. The function keys can select the sound effect and timer. Fig. 4 shows the block diagram of this system.

Name	Portable MP3 Player
Purpose	Playing the MP3 audio £le
Inputs	4 buttons
Outputs	eraphone and Bluetooth headset
Function	Decode the digital audio
System Connectivity	USB 1.1
System Compatibility	PC and MAC
Manufacturing Cost	$100 US
Power Source	AA Battery X 2
Physical Size	10cm X 7cm X 2cm
Weight	less than 200g

3 Hardware Architecture

Consider the internal architecture of our MP3 player. It contains such basic functions as an external interface, the embedded memory, digital signal processor(DSP) and CPU. The external interface is typically a Universal Serial Bus. The ¤ash memory

used to store the digital music will vary depending on the actual player. The MPEG3 decoder implemented by the DSP decompresses the data stored in the ¤ash memories to create the audio bit stream, which the audio circuitry converts from the digital audio bit stream to analog and drives the external speakers.

The embedded memory contains the ROM and SRAM. The ROM stores the data for encoding the MP3. 4k word of size is suf£cient. And the SRAM stores the temporary data during the process. The SRAM size is also 4k words.

The MPEG decoding is the most computation-consuming process. There are many analysis about the performance requirement during the different quality and algorithm. In general, we need at least 10 MIPS to 20 MIPS computation power to handle the decoding as well as the sound effect. TI's DSP TMS32C54 series provide 80MIPS to 160 MIPS. Furthermore, there are complete supporting in software and peripheral. Using the TI's DSP can reduce the time-to-market and the cost

The bluetooth headset elements the troublesome wire of traditional earphone. It let you free from the MP3 player itself. It is convenient to share the same headset with the mobile phone due to the bluetooth is a mature product. When you getting a phone call, you do not need to pause the MP3 player. The headset can switch to the phone automatically without touching your player.

Finally, the CPU connects to the user interface, display and buttons, and it also controls the operation of the MP3 player. The performance requirement of CPU is lower then DSP. The maximal bandwidth of microcontroller is the interface to USB transceiver and Flash memory. The full speed of USB 1.1 is 20Mbps or 2.5MB. And the write operation of ¤ash memory is slower than ROM and SRAM. Due to the lower performance requirement, we can select a low-end microprocessor with lower cost. The 8051 series is a better choice in cost and performance ratio.

Fig. 4 shows the detail hardware architecture.

4 Software Architecture

The operation mode of MP3 player contains two mode: download digital audio data and play the music. When it in download mode, the system is connected to host through the USB. The 8051 controller receives the data from USB transceiver. And then 8051 writes the data into the ¤ash memory. At the same time, other components in system are in halt mode. Only the LCD display indicates the state of download mode. After downloading the digital music, users can push the play button to start the playing process. The controller enables the DSP to start the decoding process. The buttons and LCD are available controlled by the 8051 during the playing. The DSP fetches the data stored in Flash memory and ROM, and decodes the MPEG data to wave data. The SRAM can store the temporary data in process. When playing the music, the bluetooth module are also in working. Users can use the headset to receive the the wave through the bluetooth. Fig. 4 and Fig. 4 describe the ¤ow.
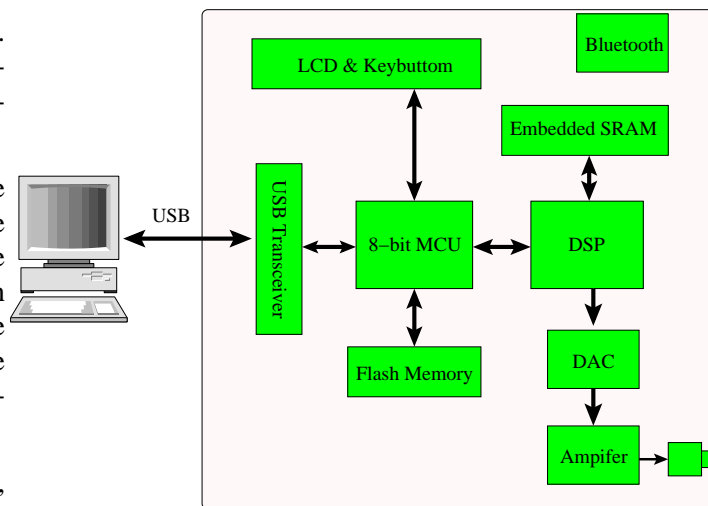

Figure 2: The block diagram of MP3 Player.

5 Cost estimation

The overall cost should be $100 to $200 as a better competitive price. We can estimate our product roughly. The Table 1 illustrates the cost of each component.
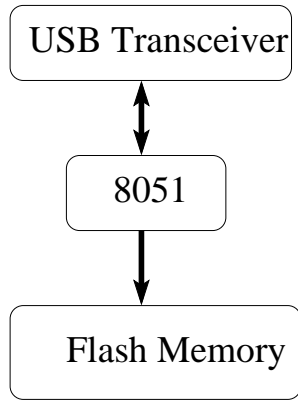
3

In download mode

USB Transceiver

8051

Flash Memory

Figure 3: The software architecture in download mode.

USB Tranciver

Buttons

DAC   Amp

LCD   Controller 8051   DSP TI   Bluetooth

System Bus

Flash 64MB   ROM 4K   SRAM 4K
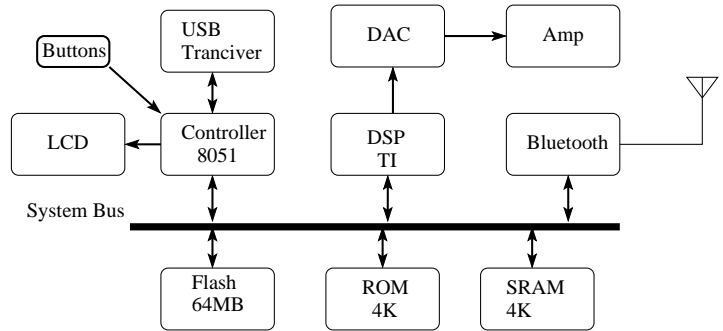
Figure 5: MP3 player hardware architecture.

In playing mode

Ampifer

LCD & Buttons   DAC

Bluetooth Module
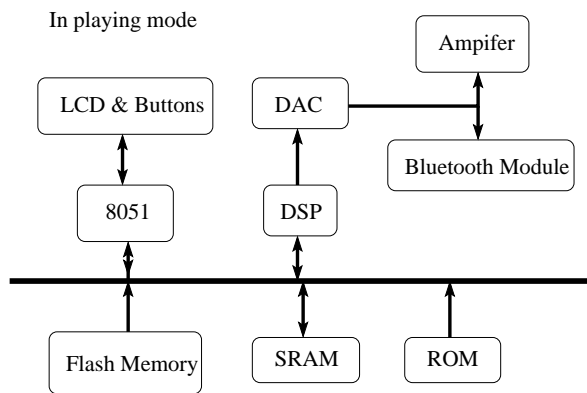
8051   DSP

Flash Memory   SRAM   ROM

Figure 4: The software architecture in playing mode.

Table 1: The cost estimation of every component.

Type	Description	Price in $US
DSP	TMS32C45xx	10
CPU	8051	2
Flash	64MB	30
SRAM and ROM	4k/4k	10
Bluetooth module		5
USB transceiver	Philips PDIUSBD12	2
LCD and other		10
Total		70

4